

What Does SF/ISM Have to Do with Climate Change?

Frank H. Shu

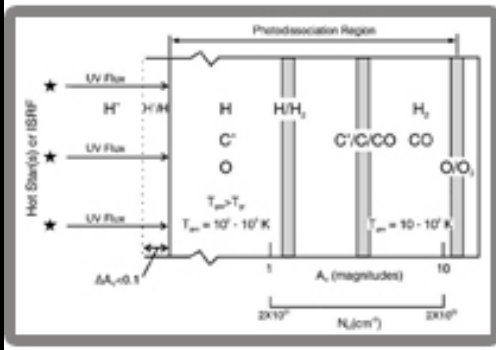
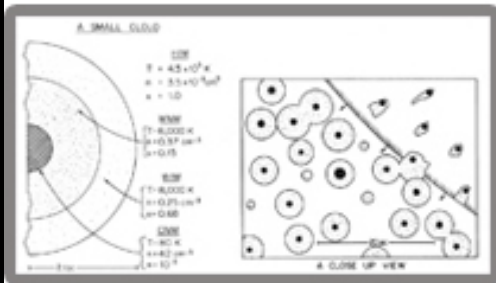
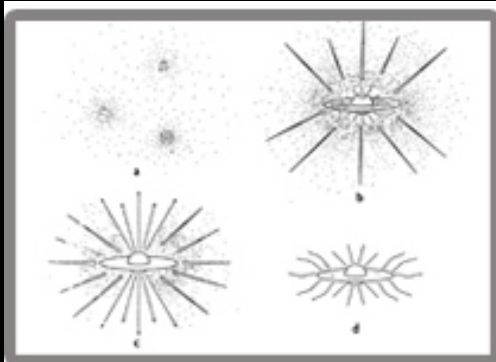
Thirty-Five Years Earlier & Later



HX Team members: M. J. Cai, F. T. Luo, P. T. P. Ho, R. E. Taam, Y. D. Huang, R. Krasnopolsky, T. S. Wei, S. Chien, S. J. Zheng, K. H. Chien, S. K. Wu, N. H. Tai

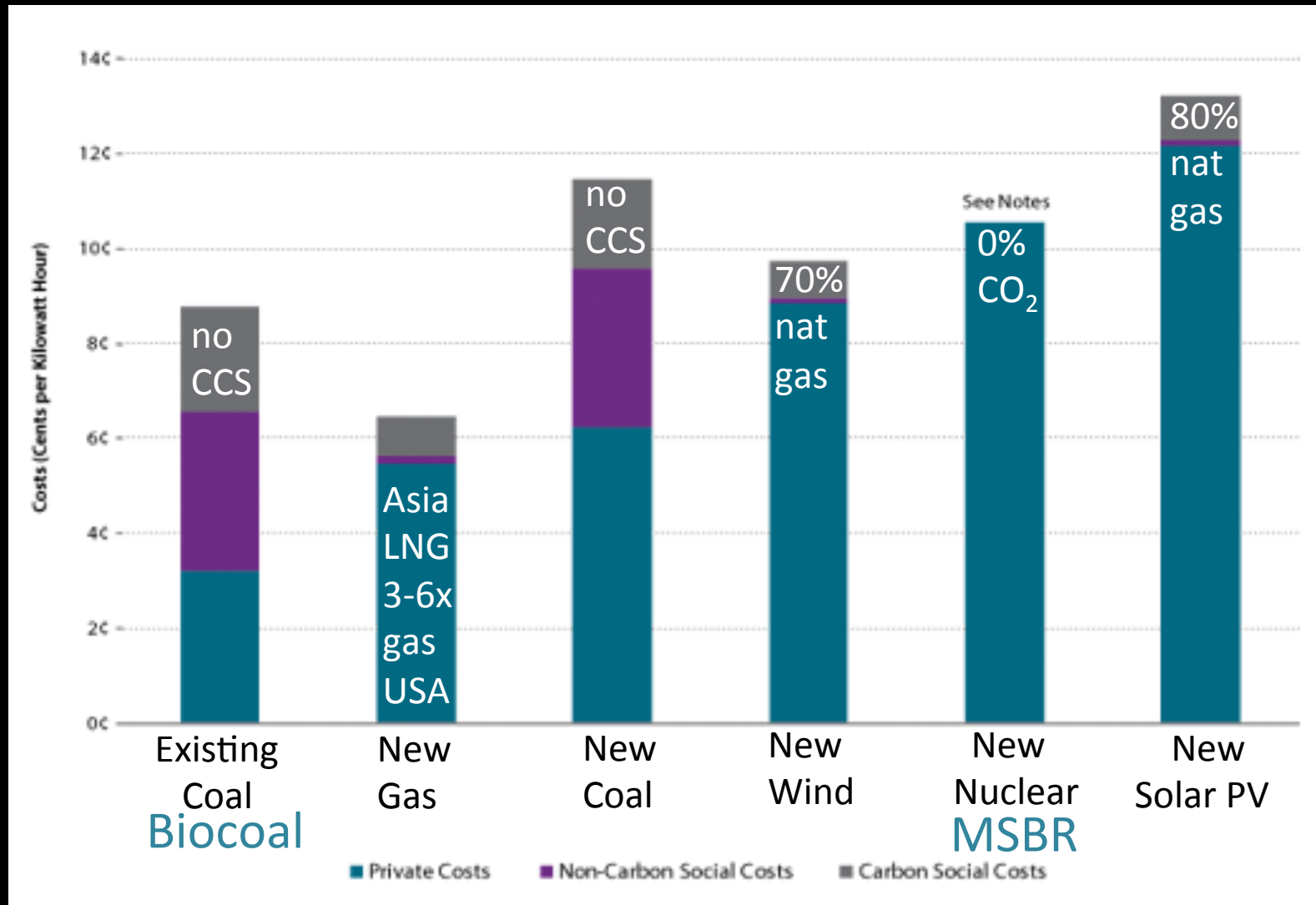
X-Men: S. Lubow, S. Terebey, F. Adams, S. Lizano, S. Ruden, J. Najita, D. Galli, E. Ostriker, A. E. Glassgold, H. Shang, Z. Y. Li, M. Cai, S. Mohanty, T. Lee, E. Rehm, M. Gounelle. Honorary m: D. H. Magneto(s) & Mystique(s): C. Heiles, G. Basri, C. M., D. Crutcher, T. Troland, G. Marcy.

The Best of H/M/S



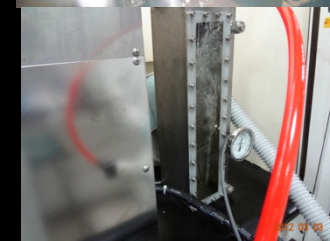
- **Features in common? (apart from BP)**
 - Not one-shot deal but an ecosystem
 - Sustainable
 - Recyclable
 - Implied $t < 0$ and $t > 0$
- **Analog with Climate Change**
 - Energy, Economics, Environment
 - Now is pivotal instant $t = 0$
 - Not yet decided whether our civilization will be a brown dwarf or a star
 - Continued contraction to ever dimmer state
 - Stabilization to My-Gy of luminous development
 - Ultimate question: can we transition from FF to renewable & nuclear E responsibly?

Energy, Economics, Environment: Cost of New Electricity in USA



The Hamilton Project, Brookings Institution 2011

Cranked Tabletop Supertorrefaction: Biomass in 300 °C NaAc/KAc w/o O₂ for 10 min



Goal: Biocoal cheaper than coal, transportation fuel cheaper than petroleum, syngas cheaper than nat gas w/o subsidies



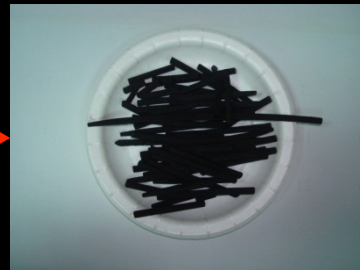
bamboo stick



bamboo pieces



chopsticks



toothpicks



leucaena



orange peel



banana peel

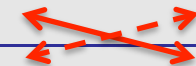


grapefruit rind



Taipower Assay of Bamboo Biocoal

Quality	Biocoal	Bituminous Coal
Heating value	25.7 MJ/kg	> 25 MJ/kg good
Grindability Index	67	> 45 acceptable
Fixed carbon	49.55%	44.9% to 78.2%
Remaining VOC	36.11%	9.1% to 36%
Sulfur content	0.06%	0.7% to 4% scrub
Ash content	5.69% potash	3.3% to 11.7%
Moisture content	8.65% if dried	2.2% to 15.9%

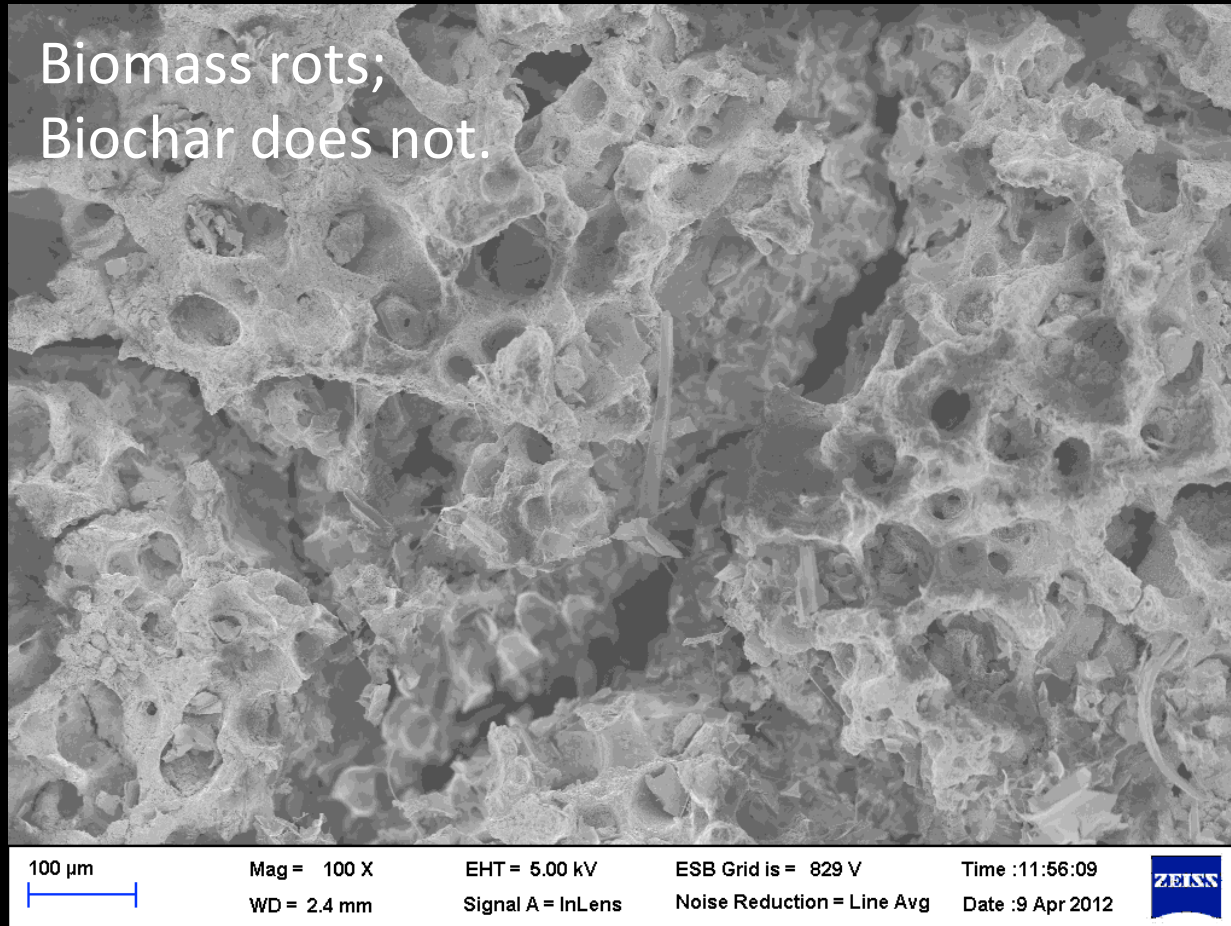


Commercialization advantages:

- 1) Hundreds x throughput conventional gas-methods, even w salt recovery
- 2) Recover hydroxyacetone, furfural, acetic acid, acetone, methanol, syngas

Use of Biochar as Soil Amendment or for Water Filtration (key is porosity – like ISM)

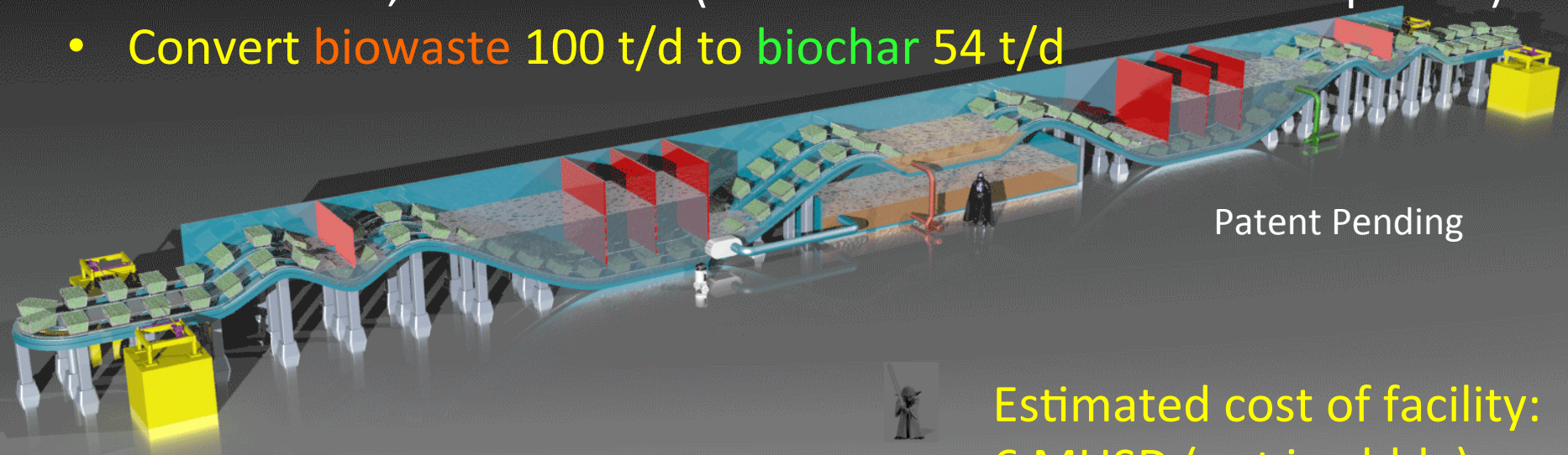
Biomass rots;
Biochar does not.



BET area = 6.3777 m²/g for supertorrefaction at 300 °C

Continuous Process (C) Supertorrefaction

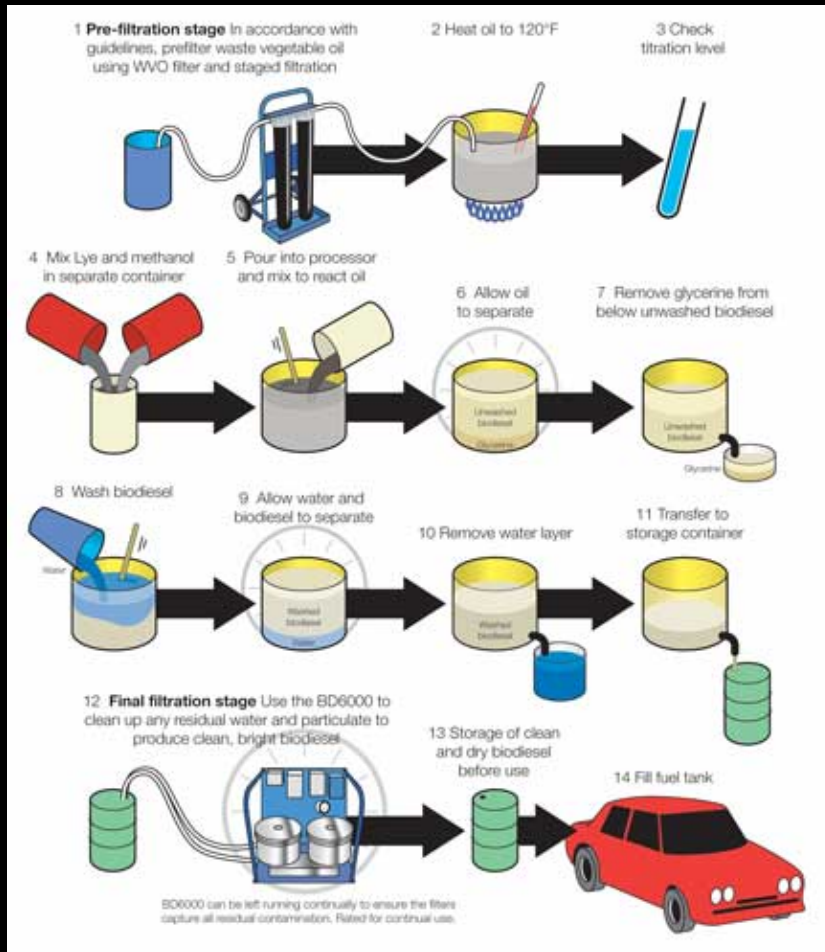
- **Supertorrefy biomass in 300 °C molten salt for 10 min**
 - **Charcoal:** biocoal C-neutral; biochar (soil amendment) C-negative
 - **Methanol:** transesterify veg oil into biodiesel (add **furfural, hya**)
 - **Acetic Acid:** wash biochar, distill to recover salt & acetic acid; salt-cycle conversion to **acetone**; **methanol + acetic acid** → **MeAc**
 - **Bottom ash:** **K₂O, MgO, CaO** (+ **water** → **valuable hydroxides**)
 - **Water:** facility use & coolant in turbulent heat exchangers
 - **Syngas:** mostly **CO₂** & **CO** for heat or molten salt fuel cell.
 - All **resource**; zero **waste**! (Model for sustainable development)
 - **Convert biowaste 100 t/d to biochar 54 t/d**



Action figures (TM & © Lucasfilm)

Estimated cost of facility:
6 MUSD (not inc bldg)

Associated Green Businesses: Biodiesel from Used Vegetable Oil



www.southboroughfire.com

Collect & filter **used vegetable oil**.

Pour methanol/MeAc & hydroxide into warm oil; let glycerol settle, then drain (useful for furfural/hya sep)

Wash with **water**; let settle & drain from transesterified oil (**biodiesel**).

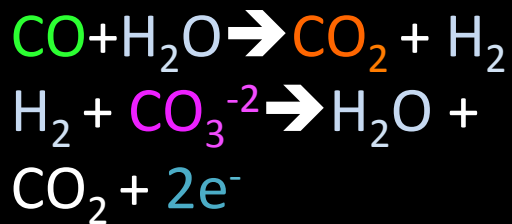
Filter once more; distribute; pump (100% usable w or w/o additives).

Associated Green Businesses: Acetone as Feedstock for Unleaded Airplane Fuel

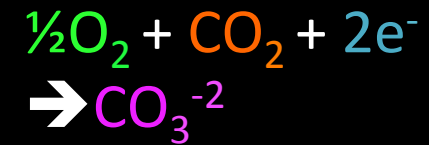
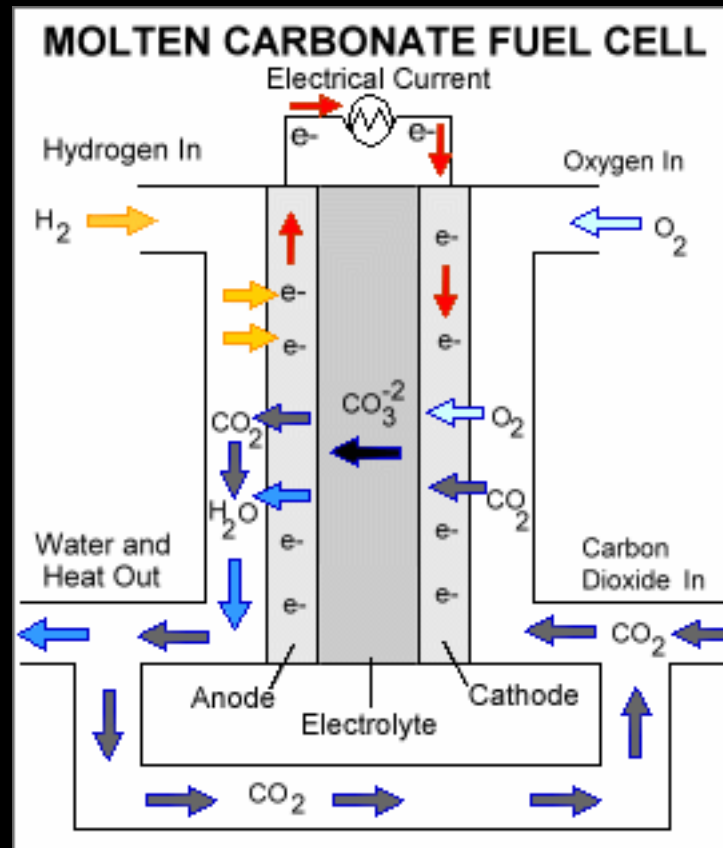


Swift Enterprises
W. Lafayette, IN

Associated Green Businesses: CO in Syngas into Electricity by Fuel Cell



Challenge: 5 yr usable lifetime from corrosion by hot carbonate salt.



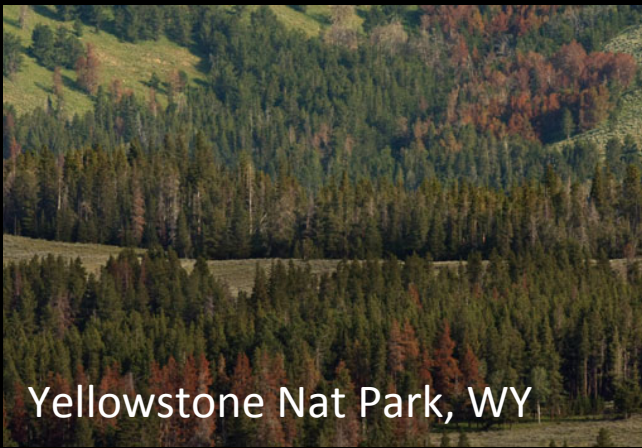
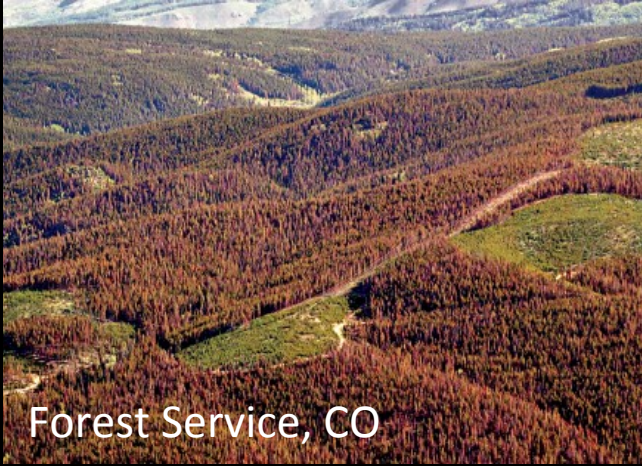
For pilot project, burn non-condens VOCs to recover salt & acetic acid.

Reclamation of Damaged Lands: Abandoned Silver Mine (As, Hg, Cd, Zn)



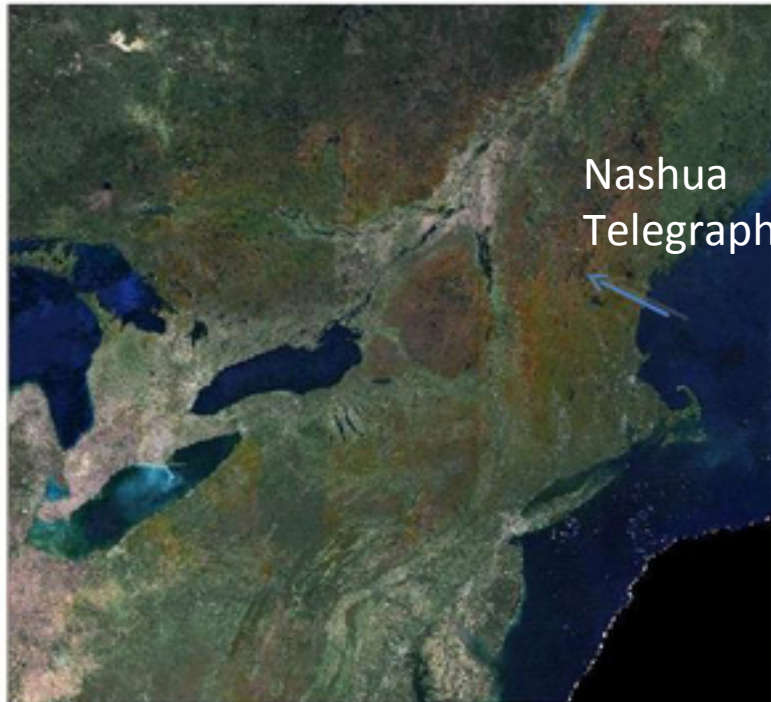
- Biochar soil amendment (0.23 t/d) from beetle-infested pine trees
- With 1 B supertorrefier, 26 t/d biochar
- Each year $8,900 \text{ t} / (200 \text{ t ha}^{-1}) = 44.5 \text{ ha} = 0.5 \text{ UCB campus/yr}$

Western Pine Beetle Infestation



CO & WY: 100,000 trees fall/d = 200,000 t/d = 4,200 B supertorrefiers transported to remote sites by truck

Eastern Red Maple Fungus



October 8-15, 2003

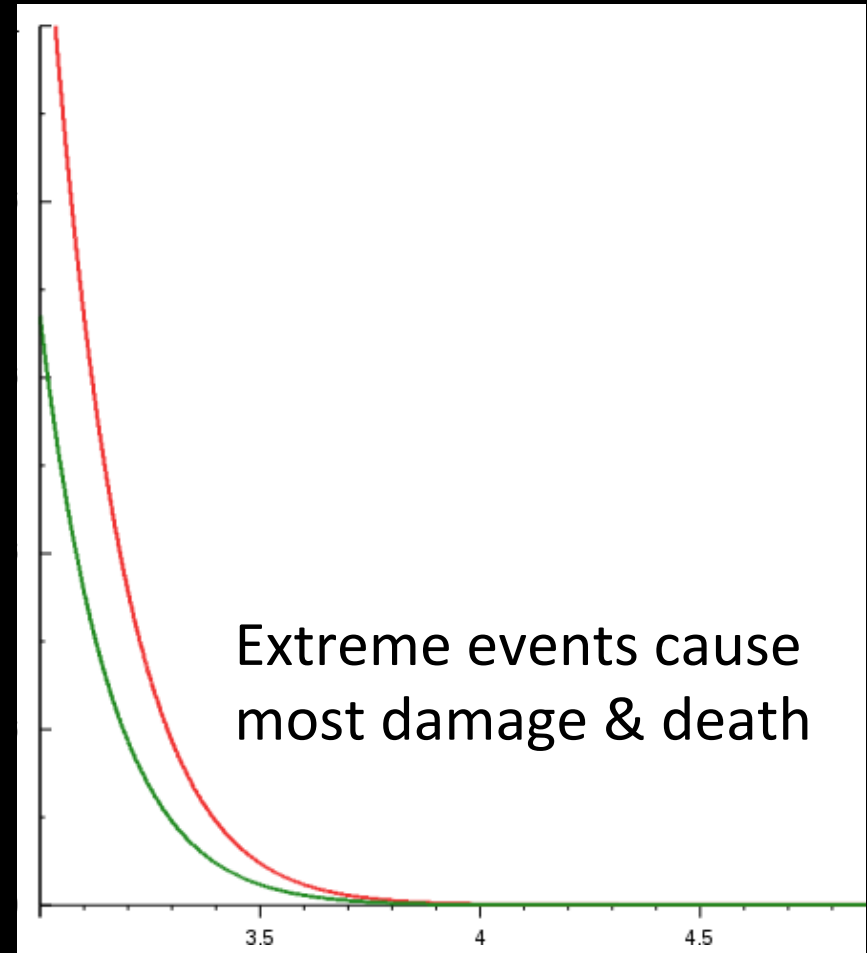
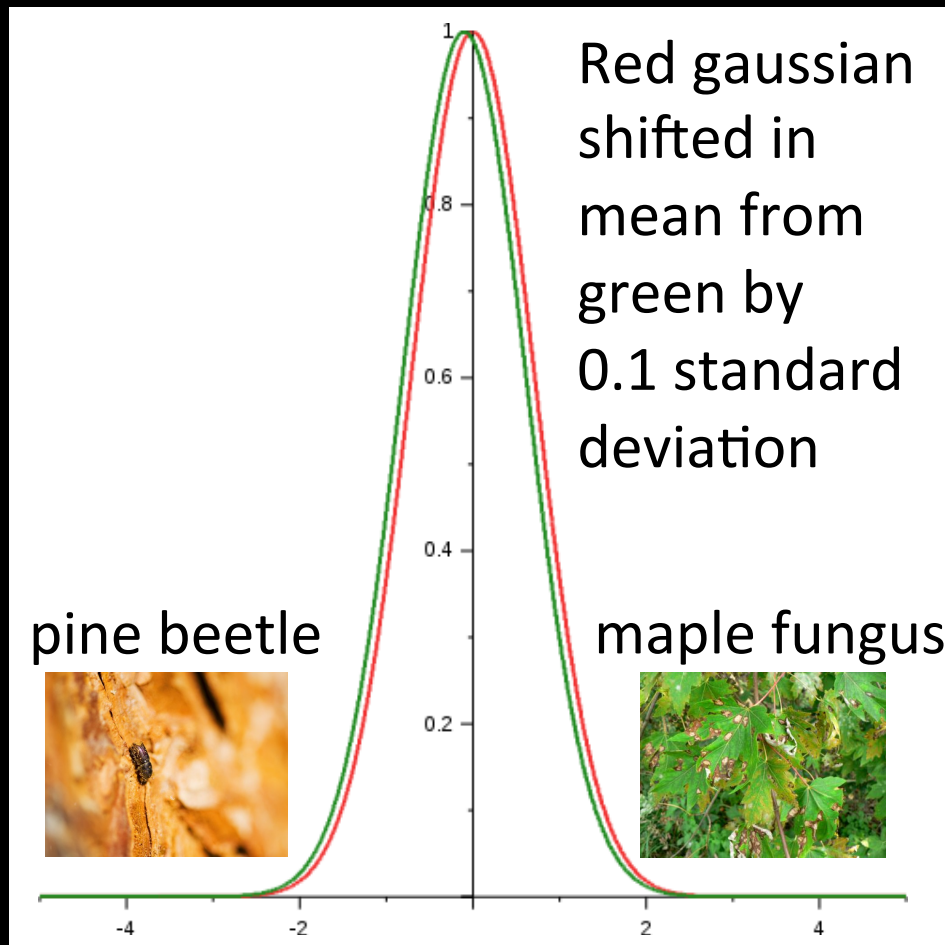


October 8-15, 2005

NASA MODIS Data

Decrease in maple sugar content: 3% to 1%

Climate Change Is Here, Making Extreme Events More Likely

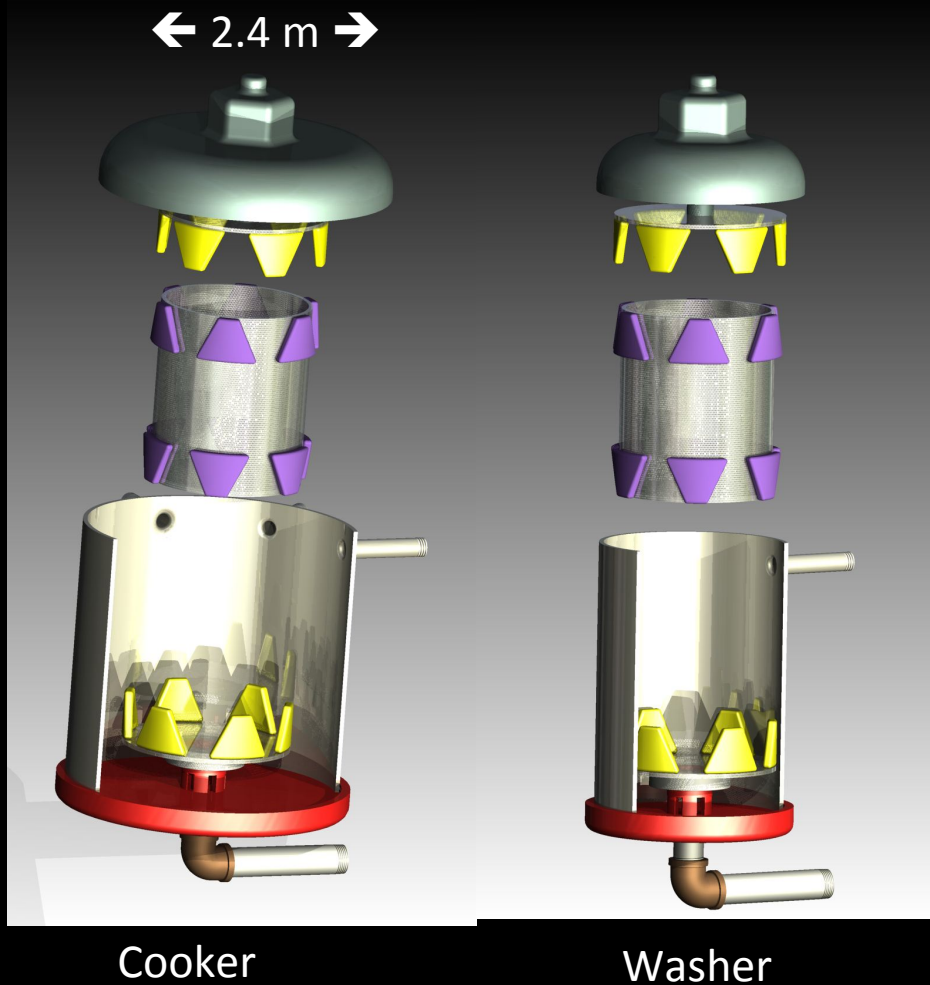


Drought

Damp

Storm category

Batch Process (B) Supertorrefier



Heat of Vaporization:

Water: 2.257 MJ/kg

Acetic Acid: 0.395 MJ/kg

1 Cooker + 6 Washers
net 26 t/d biochar;
salt & acetic acid separated
& recovered by heating

Demonstration Project (Leucaena):
Penghu Islands (Pescadores)

Supertorrefy 17,000 t/yr Leucaena/Dead Pine in TW/US

Item	Cost KUSD	Item	Wt x KUSD/t	Benefit KUSD
10 staff	300/600			
Biomass	680	Methanol	241x0.44	106
Equip ^a	116	Furfural/Hya	24 x1.00	24
Repair ^b	50	Acetic Acid	1,400x0.50	700
Transp	10	CaMgK ₂ Ac ₂ ^e	Buried biochar	0
Port Gen ^a	1	CO	1,630x0 ^d	0
Enh VOCs	0 ^c	Biochar	8,900x0.038/0.072 ^f	336/636
Salt loss	9	Total		1166/1466
Total	1166/1466			

^a2MUSD equip amort 40 yr @5%. ^b2.5% cap inv.
^c90% heater eff. ^dBurnt for salt/HAc recovery.
^eFrom biomass. ^fTwice \$8/\$15 per tonne CO₂.

Employ people, not machines. Money flow: urban → rural.

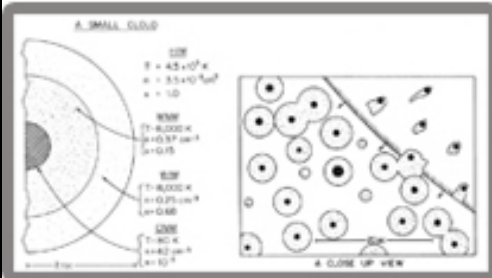
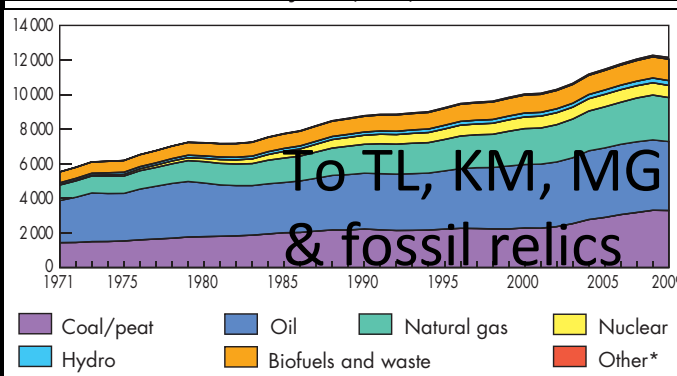
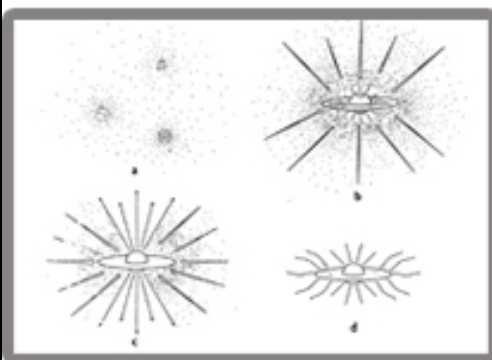
Sources of Renewable Biomass

1.6-3.0 GtC/yr feed 300,000 B supertorr; each seq. 21,000 t CO₂;
 -6.3 Gt CO₂/yr = -0.20 2011 em; 450 ppm → 350 ppm takes 250 yr.

Producer	Production rate (GtC/yr)
Open ocean (algae & kelp)	42
Tropical rainforests	37
Savanna & grasslands	19
Tropical monsoon forests	12
Boreal forests	9.6
Cultivated farm land	9.1 US crop res 0.30
Temperate deciduous forests	8.4
Temperate evergreen forests	6.6
Woodland and shrub-land	4.0
Total	147.7 need 1-2%

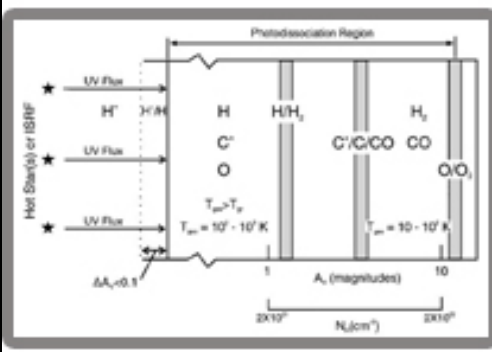
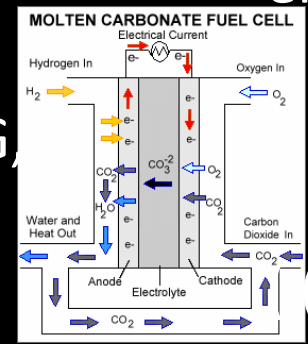
Money flow: rich countries → poor countries

Closing Credits



To those who like electricity but not magnetism (turbine)

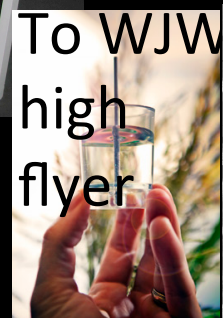
To LB, CL, AG, lovers of CO



CSFS: stellar & substellar (PB, GB, GM)

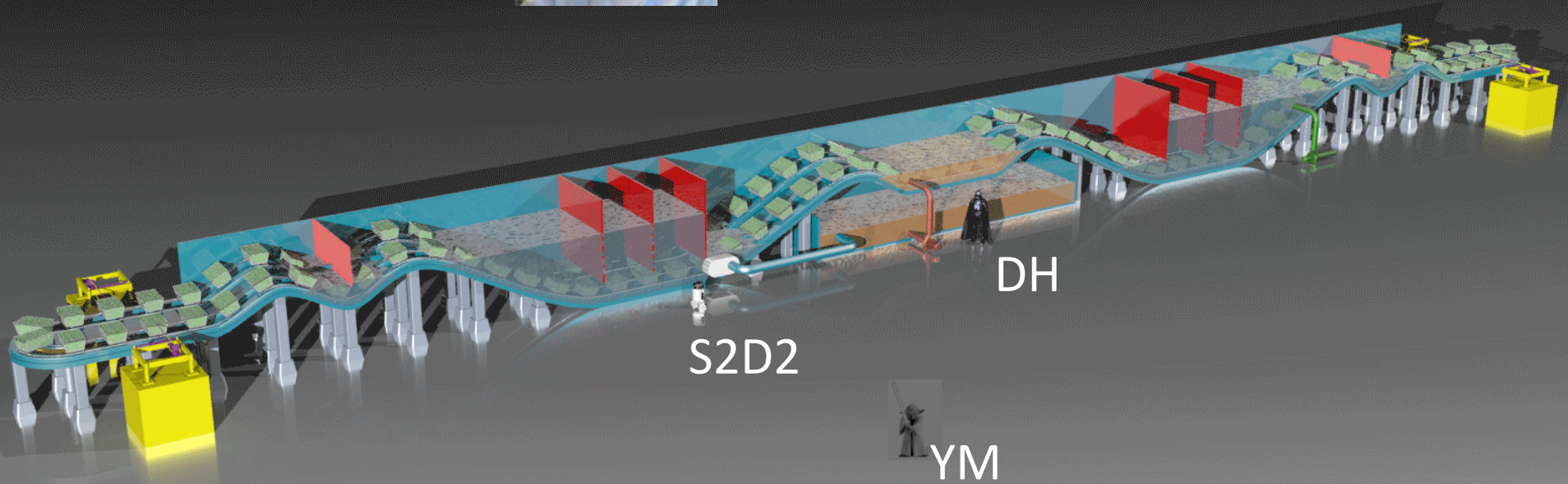


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To the Dukes of Porosity: P Ho; L Hartmann; John B, Jon W, D John; BC Koo, Fill Myers.

For this Meeting a Special Thanks!



Action figures (TM & © Lucasfilm)

Movie: M. J. Cai